National Aeronautics and Space Administration

Mars Sample Return (MSR)
Independent Review Board-2 Final Report
September 1, 2023

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MSR IRB-2 Charter

- Are the scope and cost/schedule understood and aligned?
  - What is the likely range of probable cost and schedule, drivers, and risks?
  - What is the funding profile required for the execution of the mission, and how sensitive is the mission to less than optimal funding profile guidelines?
  - Are there outsourcing, descope, or architectural options that should be considered in order to reduce technical risks, and/or to improve schedule and/or cost margins?
- Does the current distribution of work across NASA centers best position the program for technical/schedule/cost success?
- Are the management approach and structure adequate, including the international partnership for a program of this scope and complexity?
- Are lessons from Mars 2020, JWST, or other flagship missions of comparable scope being considered and applied?

The IRB was able to address the elements of the charter thanks to the extraordinary level of expertise and commitment from a broad and diverse membership. The following two elements are addressed indirectly (i.e., they have no specific Findings/Recommendations), but are reflected in one or more findings.

Outsourcing: Evaluation by the IRB focused on the adequacy of the plans, required expertise (i.e., skills and experience), and the risks associated with implementation of existing contracts. MSR is a very complex mission that requires unique and proven expertise for successful development. The IRB took the validity of the two NASA Acquisition Strategy Meetings (ASM) at face value in this approach. Alternate architectures may offer an opportunity to revisit the acquisition strategy for some of the elements or components of the architecture. Evaluation of the possible sources must show credible and assured availability for mission success as part of a NASA ASM-level review.

Lessons learned: lessons such as assembling a team of the best people talent available, and actions to deal with long lead hardware and critical path items to reduce risk are being applied effectively. The latter is more important now than ever to deal with supply chain and lingering post pandemic issues. The larger and most consequential lessons noted in the Large Mission Study conducted by NASA/SMD have not or were not applied, specifically: Unacknowledged or undeclared uncertainties associated with early estimates, Ineffective system of checks and balances, Underestimated impact of recurring system design changes.

Review Methodology

- Full IRB meetings or “plenaries”
- Interviews with stakeholders, key personnel, and community members
- Meetings of IRB subpanels
  - Programmatic/Implementation Strategy
  - Present End-to-End System Design/Architecture
  - Planetary Protection/Sample Science
  - Governance/Risks and Opportunities
- Follow-up discussions with Program and Project personnel
- IRB deliberations and discussions
- IRB period of performance: May to Aug 2023
  - See detailed timeline in Appendix

The IRB spent considerable time and effort in formal and informal settings in order to develop deep and common understanding of issues within the scope of the Charter. The complexities of MSR as a large, highly constrained, high-priority science flagship mission led the IRB to create subpanels in order to organize and be able to penetrate specific areas of concern ahead of discussions at Plenary sessions with the full IRB.

Individual members were also given specific assignments for follow-through on issues, and to develop thorough understanding on potential recommendations for discussion with the broader IRB.

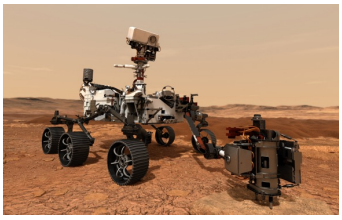
MSR Background: Pre-Phase A to Present

- NASA acquisition strategies included multiple NASA Centers and a European Space Agency (ESA) partnership from the beginning of pre-Phase A, with ESA providing a Sample Fetch Rover (SFR)/Sample Transfer Arm and the Earth Return Orbiter (ERO)/Ariane launch vehicle. *The US cost was constrained to less than $3B.*
- Industrial pre-development contracts for ERO, the SFR, and the Ariane Launch Vehicle began shortly after the first (2019) of two NASA acquisition strategy meetings.
- NASA/SMD chartered an MSR IRB-1 in 2020 to inform Key Decision Point A (KDP-A). The IRB found the total program plans to be virtually non-executable.
- Re-baselining MSR to deal with mass and other issues highlighted by IRB-1 included consideration for a second lander for the SFR. This option was eventually rejected because of added complexity/cost.
- An opportunity for Italy to contribute a second lander was eliminated because of the need to re-baseline the ESA Rosalind Franklin Mars mission due to the Russian invasion of Ukraine.
- The success of the Ingenuity helicopter on Mars resulted in the baseline placing higher reliance on the Perseverance rover, with support by helicopters as backups. The SFR was descoped.
- A variety of mounting issues with the evolving baseline including technical, schedule, and cost concerns led to the creation of IRB-2.

Acquisition strategy meetings were held by NASA in July 2019 (pre KDP-A) and May 2021 (post KDP-A).

The MSR Campaign

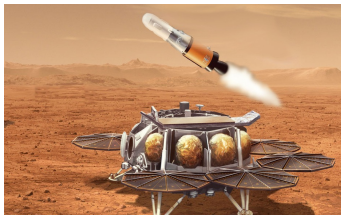
MEP



Mars 2020/Perseverance

- *Collect samples of rock, regolith, and atmosphere*
- *Cache samples on the surface for retrieval*

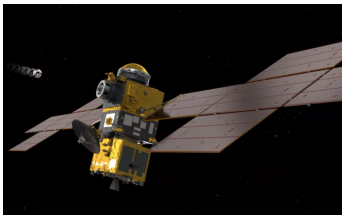
MSR



Sample Retrieval Lander (SRL)
and
Mars Ascent Vehicle (MAV)

- Retrieve samples cached onboard Mars 2020 rover or from sample depot
- *Launch samples into orbit around Mars*

MSR



Earth Return Orbiter (ERO)
and
Capture Containment and Return System (CCRS)

- *Capture and contain samples in Mars orbit*
- *Decontamination, Back Planetary Protection (BPP)*
- *Safely return samples to Earth for recovery at landing site*

MEP

Sample Receiving Project

- *Recover and transport contained samples to receiving facility*
- *Safety assessment and sample containment*
- *Initial sample science and curation*

MEP – Mars Exploration Program
MSR – Mars Sample Return

The MSR campaign spans two important programmatic efforts: the Mars Exploration Program and the Mars Sample Return.

The Imperative of Mars Sample Return

- **MSR represents the critical next step in a strategic program of Mars Exploration** spanning the past four decades. US and European orbiters and US rovers have found promising sites where life might once have existed. Samples are now being collected from one of those promising sites for return to Earth.
- **MSR returns scientifically-selected samples of Mars to address key scientific and existential questions using our most sensitive laboratories**: Did Mars harbor life in the past and if so, when? Mars was once the most Earth-like planet in the Solar System; what transformed it into the uninhabitable world that it is today?
- **MSR is a top priority of the last two surveys of the National Academies Decadal Survey of Planetary Science**, a consensus report that is respected and followed by Congress and the President.
- **MSR will inform the USA's Moon-to-Mars strategy** by characterizing environmental conditions, by validating backward planetary protection assurance, and by demonstrating launch from the surface of Mars.
- **Leadership in space exploration is a hallmark of USA's soft power in the world**. Peaceful exploration of space serves to demonstrate US technological expertise and willingness to complete what it sets out to accomplish, no matter how difficult. *NASA is succeeding at doing the seemingly impossible.*
- **China has announced plans for a Mars sample return mission** (Tianwen-3) that they claim will be launched in 2028 or 2030. These plans challenge the USA's technical, engineering, and scientific leadership in Mars exploration.
- **Mars has engaged human imagination for centuries**. It is time "to organize and measure the best of our energies and skills" (JFK, 1962) for the next giant leap to return samples now.

NASA started conceptualization of a surface MSR idea after the successful Viking landers and what those landers discovered in the first two years of surface operations (1976-1978).

From 1988 through 1997, multiple concepts for a Mars rover sample return mission were considered as a flagship to follow orbital and surface exploration by Mars Observer and multiple spacecraft in the Mars Surveyor Program.

The Mars 1998 failures of MCO and MPL led NASA to charter an independent review of the Mars Program just as a National Academy of Sciences study commissioned by NASA called for multiple MSRs. The NASA response to the failures led to a new Mars Exploration Program and architecture as a standalone Program Office reporting to the NASA Science Associate Administrator.

The new Mars Exploration Program included MSR as a step beyond the initial core program composed of orbital reconnaissance orbiters/in-situ reconnaissance and sampling and preparations for eventual sample return. Over $20B has been invested across more than four decades to arrive at this moment.

"Soft power" or "getting what you want [in international relations] through attraction rather than coercion" is a benefit of NASA's human spaceflight programs." This is also true for dramatic planetary missions. [Pathways to Exploration (NRC, 2014)]

By abandoning return of Mars samples to other nations, the US abandons the preeminent role that JFK ascribed to the scientific exploration of space in his 1962 Rice U speech: "We set sail on this new sea because there is new knowledge to be gained, and new rights to be won, and they must be won and used for the progress of all people."

The Value of Returned Samples from Mars

- Return of lunar samples during Apollo established the present paradigm of an impact-dominated early solar system and provided an absolute chronology for early events in the vicinity of Earth. ***MSR will similarly revolutionize our understanding of the inner solar system from a vantage point beyond Earth.***
- Mars Sample Return is the next step in a ***carefully crafted, science-based strategy*** for Mars Exploration: ***"Follow the Water – Habitability – Search for Life."***
- ***Whether there was or is life elsewhere in our solar system is one of the most important scientific questions we can answer***. This question is the pinnacle of a decades-long NASA program of strategic Mars exploration. The question has informed the highest scientific priority flagship mission in the last two planetary science decadal surveys.
- The samples currently being collected by the Perseverance rover are from a delta/lake deposit that is thought to have formed in an Earth-like environment early in Mars' history. ***This makes the samples of very high value in the search for ancient life beyond Earth***.
- ***State-of-the-art laboratory facilities are needed*** in order to engage the best technological and scientific capability to detect faint, difficult-to-detect signatures. ***This work is impossible to do on Mars*** with the limitations in mass and power of robotic instruments that can be brought to the Martian surface.
- China is planning to return Mars samples on a similar timetable, but lack similar scientific rigor. ***MSR will bring back carefully-selected samples that the international Mars science community has deemed are of the greatest value.***

"Origins, Worlds and Life," the NAS Decadal Strategy for Planetary Science and Astrobiology, says "key scientific objectives for Mars and, more broadly, for planetary and astrobiological science, can only be achieved via study of carefully selected Martian samples in terrestrial laboratories … Certain types of measurements (e.g., phase-specific stable and radiogenic isotopes, trace elements, nanometer-scale composition and texture, and precise organics characterization) cannot be done remotely because they require sample preparations and analytical precisions only possible in specialized laboratories." (p. 22-7) The Decadal Strategy goes on to say (p. 22-8) "In addition, sample return will allow for future analyses by instruments and techniques not yet developed. As has been the case with the Apollo samples from the Moon, future analyses are expected to yield profound results for many decades after sample return."

The key science investigations enabled by improved and novel measurements of returned samples include (summarized from Decadal Strategy text 22-7, 22-8): the identification of potential biosignatures that are difficult to detect or are not accessible to in-situ measurements; a history of liquid water (where, how long?) at the Jezero site, and determining the absolute chronology of key events in the formation of Jezero from radioisotopic dating.